

Precision livestock feeding: matching nutrient supply with nutrient requirements of individual animals

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Primary Audience: Nutritionists, Researchers, Flock Supervisors

SUMMARY

Precision livestock feeding aims to match nutrient supply precisely with the nutrient requirements of individual animals, based on real-time feedback from sensors. The benefits include greater economic returns, reduced excretion to the environment, and improved efficiency of resource utilization. Animal models must be further developed and integrated with new and existing smart machines designed to deliver the right amount of the right feed to the right bird at the right time. This will require real-time sensing technologies to provide input about the feed and feed ingredients, the environment, and the birds themselves. Sensor data will allow precise estimation of nutrient requirements of each bird in real-time, to be delivered immediately to that bird by a capable machine. Precision livestock feeding will strengthen the economic, environmental, and social responsibility pillars of sustainability.

Key words: precision feeding, nutrient requirements, smart technology, nutrient excretion, sustainability

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DESCRIPTION OF PROBLEM

The nutritionist's primary goal is to match nutrient supply to nutrient requirements. Centuries of animal nutrition studies have focused on 1) characterizing nutrient availability of feedstuffs (supply), 2) characterizing nutrient requirements of animals (demand), and 3) blending ingredients to optimally match nutrient supply to nutrient demand (formulation). To highlight this specifically for poultry, the first sentence of the National Research Council's

Nutrient Requirements of Poultry states "Formulation of balanced diets is fundamental to economical poultry production, and this process depends on a knowledge of nutrient requirements of poultry and the nutritional attributes of nutrient sources" [1]. This concept has been applied primarily at the herd or flock level, and phase feeding approaches to feeding herds and flocks have prevented oversupply of nutrients and increased efficiency [2–4]. In turn, this has resulted in greater profitability and reduced excretion of nutrients to the environment [2, 4, 5]. Achieving the objective of matching nutrient supply to nutrient requirements of individual animals has been explored in pigs [2], but it is a new concept for the poultry industry and even for poultry researchers. However, new smart technologies

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have begun to permit serious study of this approach, and as technology costs decrease, these smart technologies will allow implementation of precision feeding for individuals on an industry-wide scale.

NUTRIENT REQUIREMENTS ARE DYNAMIC

Nutrient requirements depend on each individual animal's specific and unique genome, its environment, and its stage of life [5–7]. In spite of this, research and practice aimed at increasing efficiency and reducing excretion have focused on requirements of groups of birds. Determining requirements of individual animals (and associated variation) is barely on our radar as poultry nutritionists, partly because progress has been possible with a group-level approach and partly due to the high research and implementation cost of precision feeding approaches for animals with relatively low value per individual.

There is, however, a strong value proposition for feeding animals according to their individual nutrient requirements. Feeding pigs individually with daily tailored diets reduced lysine intake by 26% and nitrogen excretion by 30% without compromising pig performance [5]. For sows, animal welfare motivated anticrute legislation, rather than potential nutritional program improvements, has driven a move to electronic sow feeders. This has presented an opportunity to differentiate feeding programs for individual sows. Information about each individual's age, parity, weight, and stage of gestation has been used to tailor feed intake in a manner that ultimately reduces feed waste and increases lactation success and longevity. A further benefit is that large amounts of data can be collected from the system that facilitates further refinement of feeding programs [5, 8].

SCOPE OF THE PRECISION FEEDING OPPORTUNITY

Nitrogen retention rates range from 57 to 60% for meat-type poultry and 46% for layers; phosphorus retention is 45 to 48% in broilers

and turkeys and only 29% in layers [4]. Although phosphorus retention is improved with dietary supplementation of phytase [9], focus on meeting nutrient requirements of individuals [2] and other innovative individualized nutrient delivery strategies [10] offers substantial opportunities for further optimization. By extension, creating smaller groups of animals with similar nutrient requirements allows some tailoring of nutrient supply. This approach reduced nutrient excretion and increased profit, thus approximating the benefits of individual feeding of dairy cows [11]. In broiler breeders, this principle is applied through a process called grading [12, 13], where pullets of similar body weight are fed according to the needs of their specific cohort. This is performed to increase uniformity of body weight and skeletal size and to facilitate management around the point of lay, but the practice is also likely to reduce nutrient excretion.

OPPORTUNITIES PRESENTED BY A NOVEL PRECISION FEEDING SYSTEM

A novel precision feeding system was developed recently in Canada [14]. Until now, the precision feeding system has provided precise measured amounts of feed to individuals. In broiler breeders, the birds gain entry to a feeding station sequentially, BW is measured, and based on a comparison of BW in real time with the desired target BW, the bird is either ejected from the feeding system (if $BW \geq \text{target BW}$) or fed (if $BW < \text{target BW}$) and then ejected from the system. A next-generation system is being manufactured that will provide the additional capability to provide feed with a variety of nutrient specifications to tailor both the amount and composition of the feed to each bird's needs. Thus, in the very near future, we will be able to adjust nutrient intake to match requirements of individual birds in real-time, based on their state-specific needs as estimated from sensor data. As the cost of technology comes down, it is conceivable that the benefits of precision feeding will outweigh the cost.

PRINCIPLES OF PRECISION AGRICULTURE

Nutrient requirements are affected by genotype and environment. Together, factors such as growth potential, composition of gain, carcass composition, environmental temperature, egg production rates, and egg composition affect the costs of maintenance, gain, and egg production. The immediate challenge is to quantify the response of individual birds to nutrient intake levels. Of key importance is individual bird-to-bird variation, which then must be associated with identifiable traits such as genotype (breed and sex), age, BW, body composition, growth rate, feed intake level, environmental conditions (e.g., temperature, relative humidity, air quality), and health status [4, 7, 15–22].

Precision livestock feeding aims to match nutrient supply precisely with the nutrient requirements of individual animals, based on real-time feedback from sensors. Strategies for matching nutrient supply to nutrient requirements depend on reliable animal models. Currently, in poultry, we know a lot about the ways that diet manipulation affects performance and excretion [23, 24]. However, most of our knowledge and virtually all of commercial application of these concepts are limited to the flock level. Models currently in use are generally limited to evaluating alternative management strategies (and implementing) at an enterprise level [25–28]. In the future, simulation models will underpin real-time control of smart systems that will optimize animal productivity, carcass quality, health and welfare, and profitability [25]. These animal models will be incorporated into precision livestock farming systems. They will run in real time to both evaluate the needs of individual animals and electronically control feeding systems to deliver nutrients according to individual requirements. Existing or new smart technologies will use a variety of sensors to identify individual animals and monitor their weight and body composition and measure important environmental variables and individual or flock health status. These integrated systems will then control feed composition and intake to meet each animal's needs. Emerging technologies such as machine

learning and artificial intelligence will continuously improve and optimize the system based on bird performance, environmental and economic outputs, sustainable production objectives, and input costs.

CONCLUSIONS AND APPLICATIONS

1. Precision livestock feeding aims to match the nutrient supply for individual animals with their unique requirements, in real time. This approach holds significant promise for reducing cost and nutrient excretion associated with livestock production.
2. A shift in thinking from flock to individual animal level is needed first by researchers and subsequently by the poultry industry before the benefits of precision feeding can be realized.
3. Clearly defined sustainable production goals are needed to achieve the best possible poultry production systems.
4. Nutrient response models must be further developed to respond to sensor data providing real-time input about environmental conditions, individual bird status, and nutrient availability.
5. Integration of animal models with sensor technologies and affordable machines to meter tailored diets to individuals are needed.
6. Precision livestock feeding promises greater economic returns, reduced excretion, and greater resource utilization efficiency. It is a key strategy to produce poultry in a socially responsible manner.

REFERENCES AND NOTES

1. NRC. 1994. *Nutrient Requirements of Poultry*, 9th rev. ed. The National Academy of Sciences, Washington, DC.
2. Pomar, C., L. Hauschild, G.-H. Zhang, J. Pomar, and P. A. Lovatto. 2009. Applying precision feeding techniques in growing-finishing pig operations. *Rev. Bras. Zootec.* 38:226–237.
3. Nahm, K. H. 2002. Efficient feed nutrient utilization to reduce pollutants in poultry and swine manure. *Crit. Rev. Environ. Sci. Technol.* 32:1–16.
4. Powers, W., and R. Angel. 2008. A review of the capacity for nutritional strategies to address environmental challenges in poultry production. *Poult. Sci.* 87:1929–1938.

5. Andretta, I., C. Pomar, J. Rivest, J. Pomar, and J. Radunz. 2016. Precision feeding can significantly reduce lysine intake and nitrogen excretion without compromising the performance of growing pigs. *Animal* 10:1137–1147.
6. Brossard, L., N. Quiniou, J. Y. Dourmad, and J. van Milgen. 2012. Accounting for individual variability in modelling the response of pigs to the nutrient supply. *INRA Prod. Anim.* 25:17–27.
7. Archer, J. A., E. C. Richardson, R. M. Herd, and P. F. Arthur. 1999. Potential for selection to improve efficiency of feed use in beef cattle: a review. *Aust. J. Agric. Res.* 50:147–161.
8. Mendoza, O. F., and A. M. Gaines. 2016. Crate-free sow housing and electronic feeding systems: a value proposition for improved sow nutrition. *J. Anim. Sci.* 94:42.
9. Singh, P. K. 2008. Significance of phytic acid and supplemental phytase in chicken nutrition: a review. *Worlds Poult. Sci. J.* 64:553–580.
10. Keshavarz, K. 1998. Investigation on the possibility of reducing protein, phosphorus, and calcium requirements of laying hens by manipulation of time of access to these nutrients. *Poult. Sci.* 77:1320–1332.
11. Cabrera, V., F. Contreras, R. D. Shaver, and L. Armentano. 2012. Grouping strategies for feeding lactating dairy cattle. Accessed Jan. 2020. https://www.researchgate.net/publication/290489430_Grouping_Strategies_for_Feeding_Lactating_Dairy_Cattle.
12. Aviagen. 2018. *Ross Parentstock Management Handbook*. Aviagen, Huntsville, AL.
13. Cobb-Vantress. 2016. *Cobb Breeder Management Guide*. Cobb-Vantress, Siloam Springs, AR.
14. Zuidhof, M. J., M. V. Fedorak, C. A. Ouellette, and I. I. Wenger. 2017. Precision feeding: innovative management of broiler breeder feed intake and flock uniformity. *Poult. Sci.* 96:2254–2263.
15. Zhang, G. F., D. W. Liu, F. L. Wang, and D. F. Li. 2014. Estimation of the net energy requirements for maintenance in growing and finishing pigs. *J. Anim. Sci.* 92:2987–2995.
16. Sakomura, N. 2004. Modeling energy utilization in broiler breeders, laying hens and broilers. *Rev. Bras. Cienc. Avic.* 6:1–11.
17. Rabello, C. B., N. K. Sakomura, F. A. Longo, H. P. Couto, C. R. Pacheco, and J. B. Fernandes. 2006. Modelling energy utilisation in broiler breeder hens. *Br. Poult. Sci.* 47:622–631.
18. Pishnamazi, A., R. A. Renema, D. C. Paul, I. I. Wenger, and M. J. Zuidhof. 2015. Effects of environmental temperature and dietary energy on energy partitioning coefficients of female broiler breeders. *J. Anim. Sci.* 93:4734–4741.
19. Hadinia, S. H., P. R. O. Carneiro, C. A. Ouellette, and M. J. Zuidhof. 2018. Energy partitioning by broiler breeder pullets in skip-a-day and precision feeding systems. *Poult. Sci.* 97:4279–4289.
20. Arthur, P. F., and R. M. Herd. 2005. Efficiency of feed utilisation by livestock — implications and benefits of genetic improvement. *Can. J. Anim. Sci.* 85:281–290.
21. St-Pierre, N. 1990. Biological variation: its impact on nutrient requirements, animal performance and bottom line economics. Biotechnology in the feed industry. Pages 445–462 in *Proc. Alltech's Sixth Annu. Symp.*
22. Vieira, S. L., and C. R. Angel. 2012. Optimizing broiler performance using different amino acid density diets: what are the limits? *J. Appl. Poult. Res.* 21:149–155.
23. Dozier, W. A., B. D. Lott, and S. L. Branton. 2005. Growth responses of male broilers subjected to increasing air velocities at high ambient temperatures and a high dew point. *Poult. Sci.* 84:962–966.
24. Dozier, W. A., M. T. Kidd, A. Corzo, P. R. Owens, and S. L. Branton. 2008. Live performance and environmental impact of broiler chickens fed diets varying in amino acids and phytase. *Anim. Feed. Sci. Technol.* 141:92–103.
25. Black, J. L. 2014. Brief history and future of animal simulation models for science and application. *Anim. Prod. Sci.* 54:1883–1895.
26. EFG Software 2019. EFG Software. Accessed Sept. 2019. <http://www.efgsoftware.net/>.
27. Nutriopt 2019. Broiler Economic Performance Modelling. Accessed Sept. 2019. <https://www.trouwnutrition.com/en/nutriopt/poultry-solutions/>.
28. Cargill 2019. Poultry Performance and Productivity Challenges. Accessed Sept. 2019. <https://www.cargill.com/animal-nutrition/poultry>.